Status Update and New Aerosol Products From MODIS and VIIRS Using Deep Blue Aerosol Algorithm

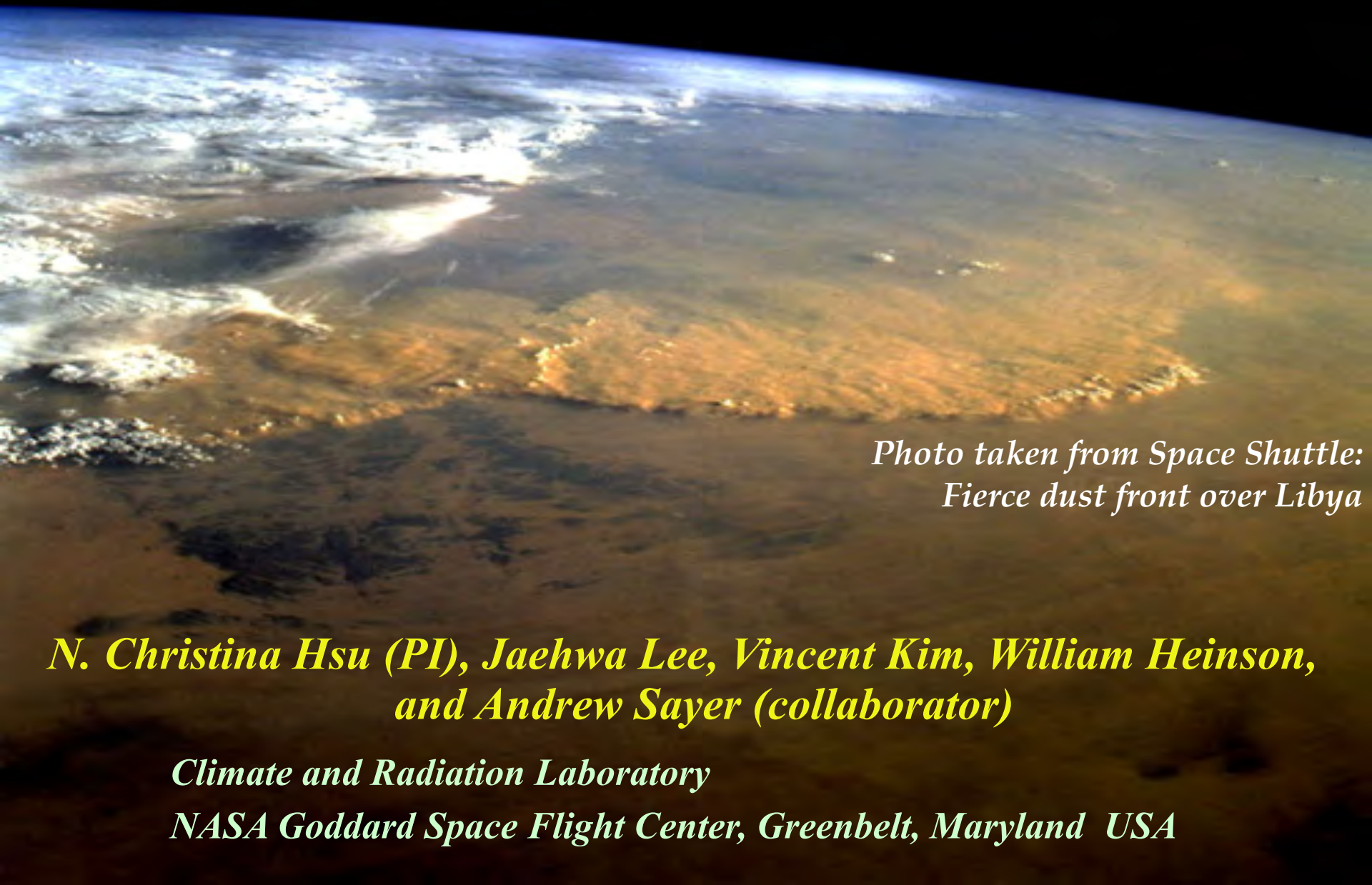

Photo taken from Space Shuttle:
Fierce dust front over Libya

N. Christina Hsu (PI), Jaehwa Lee, Vincent Kim, William Heinson, and Andrew Sayer (collaborator)

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Multi-Sensor Long-Term Deep Blue Aerosol Products

➢ ***Science Objectives*:**

- **Our primary goal is to produce consistent long-term aerosol climate data record using multiple satellite sensor data from AVHRR (historic) to SeaWiFS and MODIS (EOS-era) to VIIRS (JPSS-era)**
- **Our new VIIRS aerosol products are generated based upon *Deep Blue* algorithm (over land) (previously applied to AVHRR, SeaWiFS and MODIS) and SOAR algorithm (over ocean) (previously applied to AVHRR and SeaWiFS)**

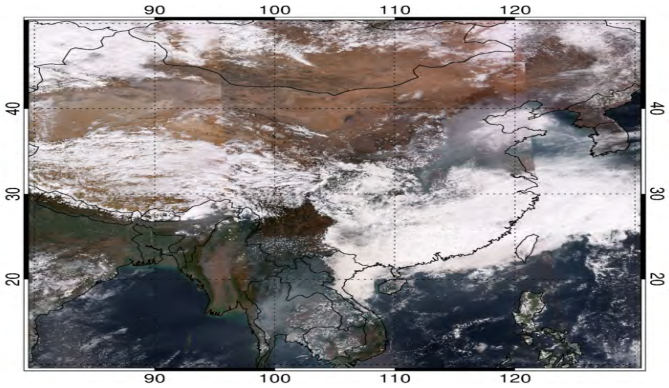
➢ ***Status of the VIIRS Deep Blue aerosol products*:**

✓ **Standard VIIRS L2 and L3 Version 1 Deep Blue products have been operational and available at LAADS since late 2018.**

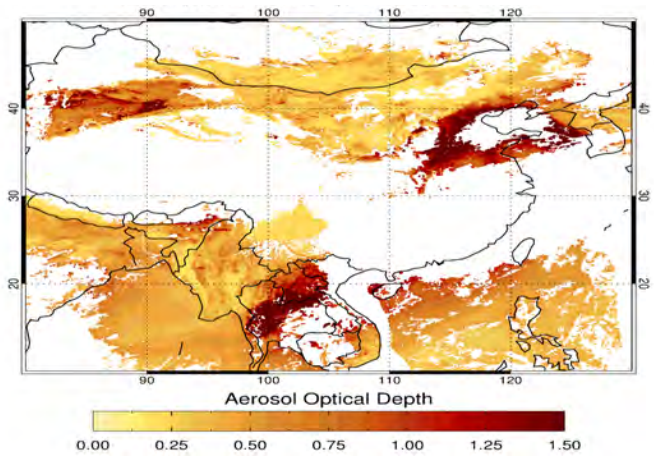
✓ **NRT VIIRS Deep Blue products also officially became operational recently via LANCE. The imagery is now available at Worldview.**

Adding Aerosol Type Product into the Deep Blue Data Suite

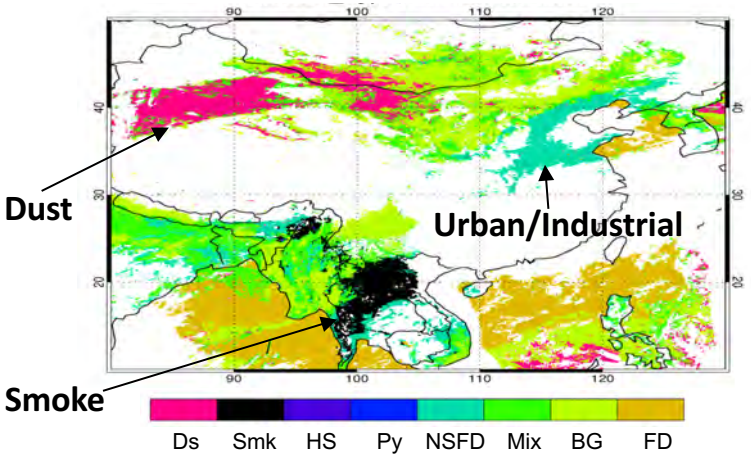
VIIRS RGB image 3/8/2014



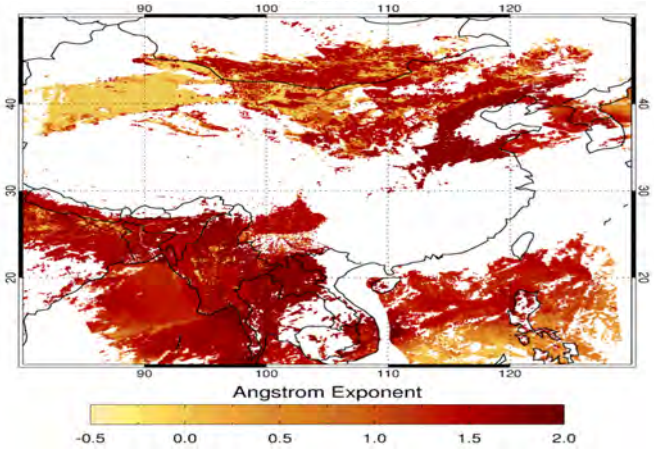
AOD at 0.550 µm



Aerosol Type

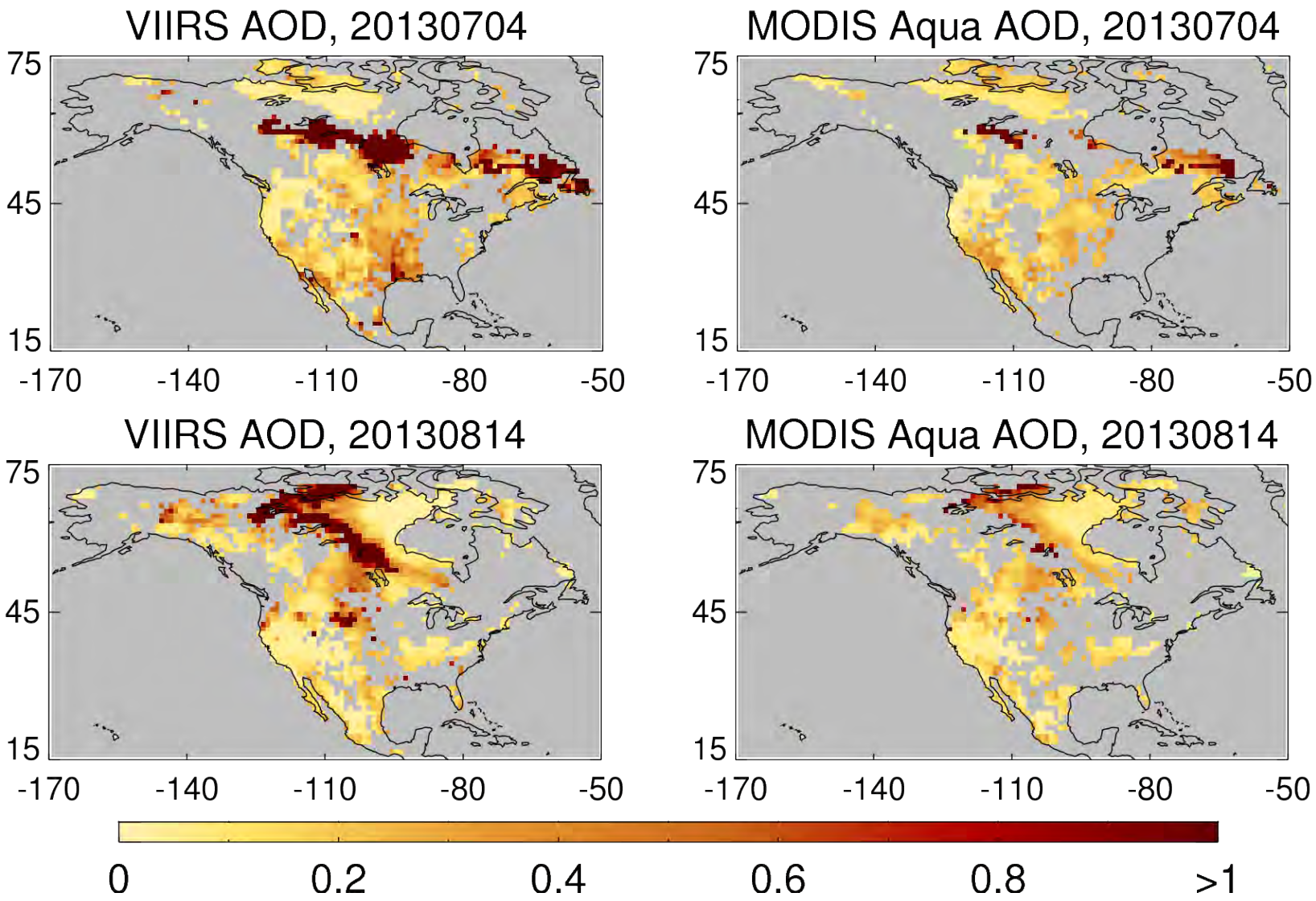


Angstrom Exponent

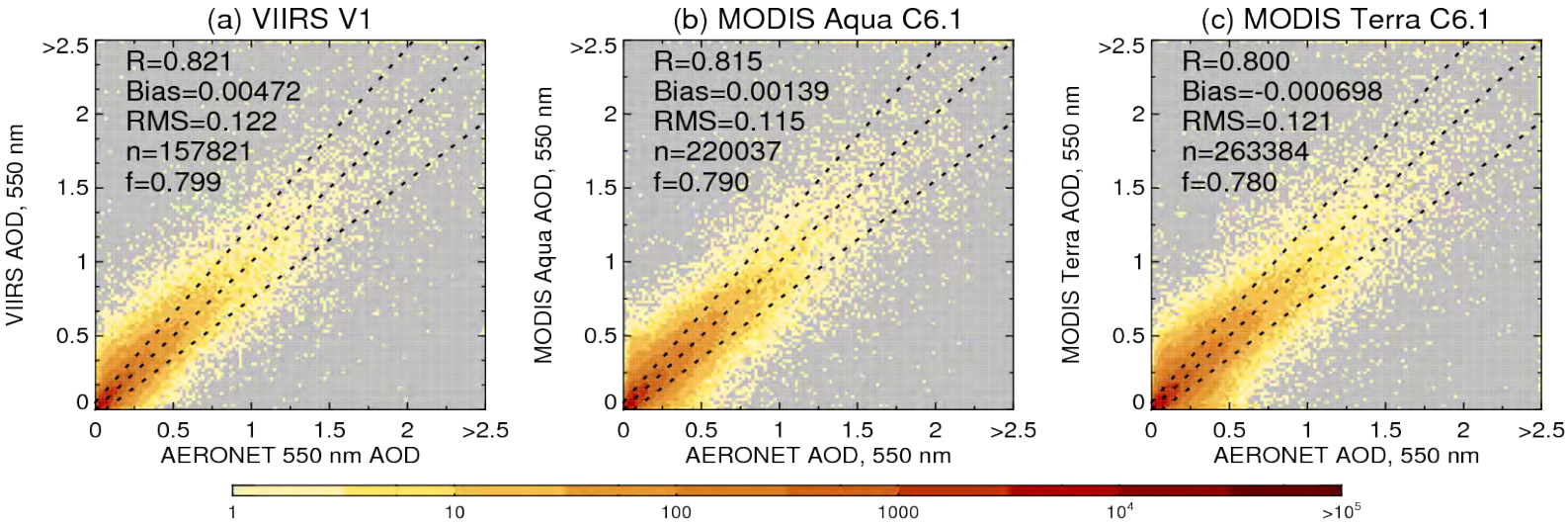


- By taking advantage of the spectral curvature approach due to the light absorption of biomass burning smoke aerosols at the blue wavelengths, we are able to distinguish smoke aerosols from other fine mode aerosols such as urban/industrial aerosols;
- Aerosol type information is derived by combining this smoke mask with retrieved AOD and Angstrom Exponent.

- **For extreme events, improved VIIRS heavy smoke/cloud detection scheme significantly increases the spatial coverage of the retrieved AOD compared to MODIS C6 over major smoke plumes**



Comparisons of VIIRS, MODIS/Terra, MODIS/Aqua over-land products with AERONET

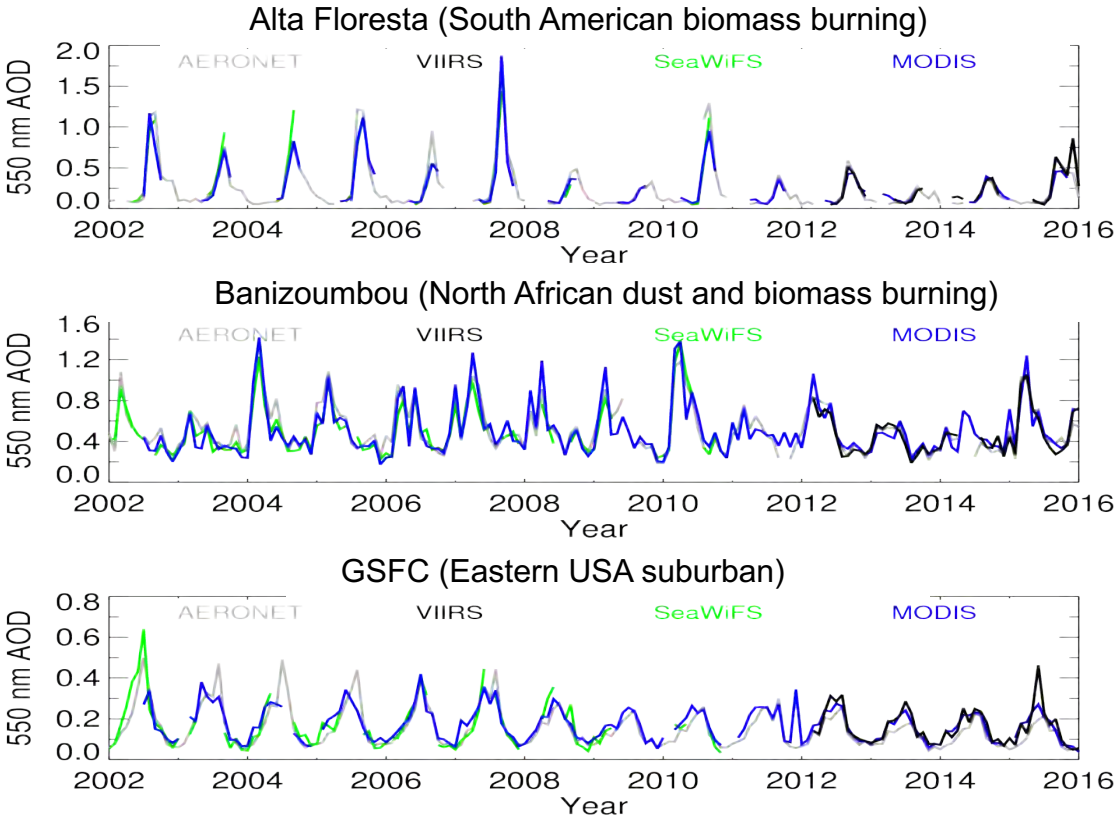


- **The performances of the VIIRS V1, MODIS/Aqua C6.1, and MODIS/Terra C6.1 Deep Blue AOD product against the AERONET on global scale are comparable. The percentage of the data that fall within the expected error of ±(0.05+20%) is slightly better for VIIRS V1 (~80%), compared to MODIS C6.1 (78% for Terra and 79% for Aqua).**

References: 1. Hsu *et al*., 2019, JGR, "VIIRS Deep Blue Aerosol Products over Land: Extending the EOS Long-Term Aerosol Data Records".

2. Sayer *et al*., 2019, JGR, "Validation, stability, and consistency of MODIS Collection 6.1 and VIIRS Version 1 Deep Blue aerosol data over land"

Time Series of Monthly Mean AOD from Multi-satellite Deep Blue data at select AERONET sites

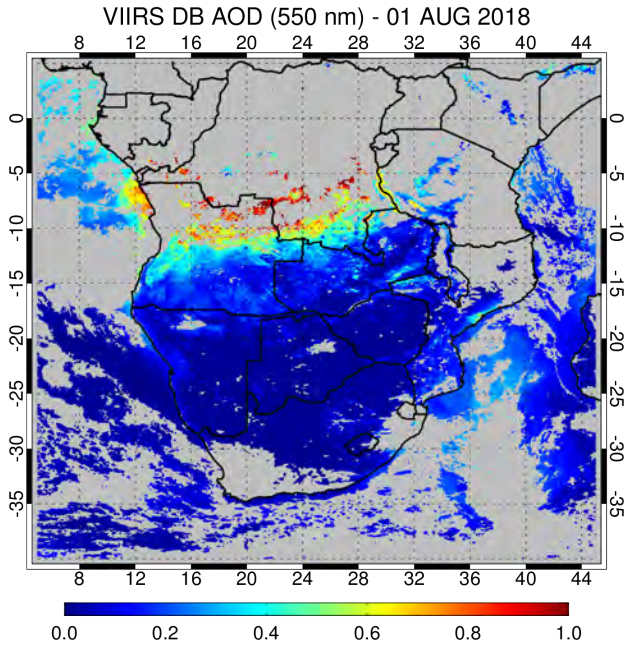


This comparison shows multi-year (2002-2015) quantitative consistency of the VIIRS AOD in comparison with our heritage MODIS and SeaWiFS results, as well as AERONET validation data.

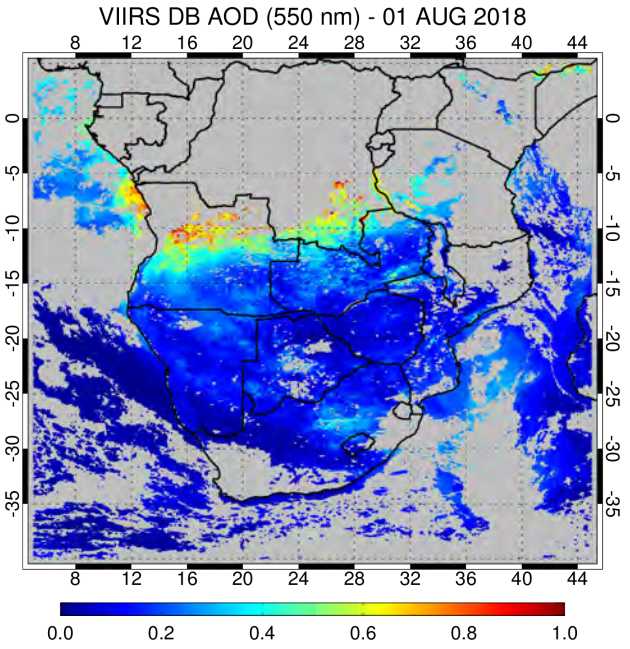
These VIIRS AOD data are generated using corrected VIIRS L1B files after we assessed the calibration of S-NPP VIIRS against MODIS Aqua and developed a cross-calibration correction for VIIRS, which was shown to decrease the uncertainty in retrieved AOD and make VIIRS results more comparable to MODIS .

Planned Improvements over High Elevation Areas for VIIRS and MODIS

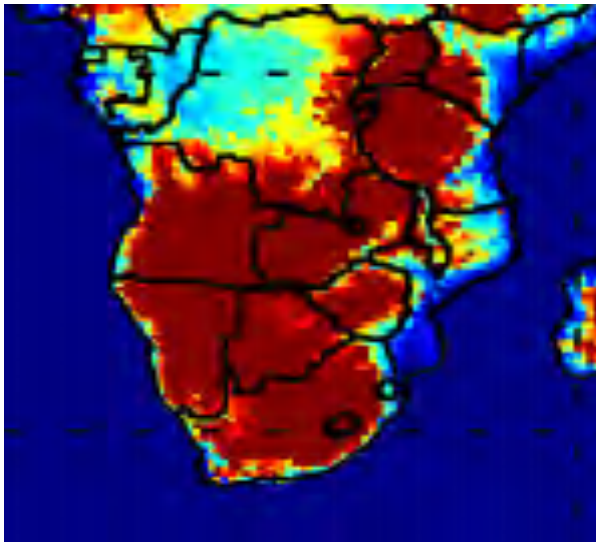
VIIRS version 1



VIIRS version 2



Surface elevation

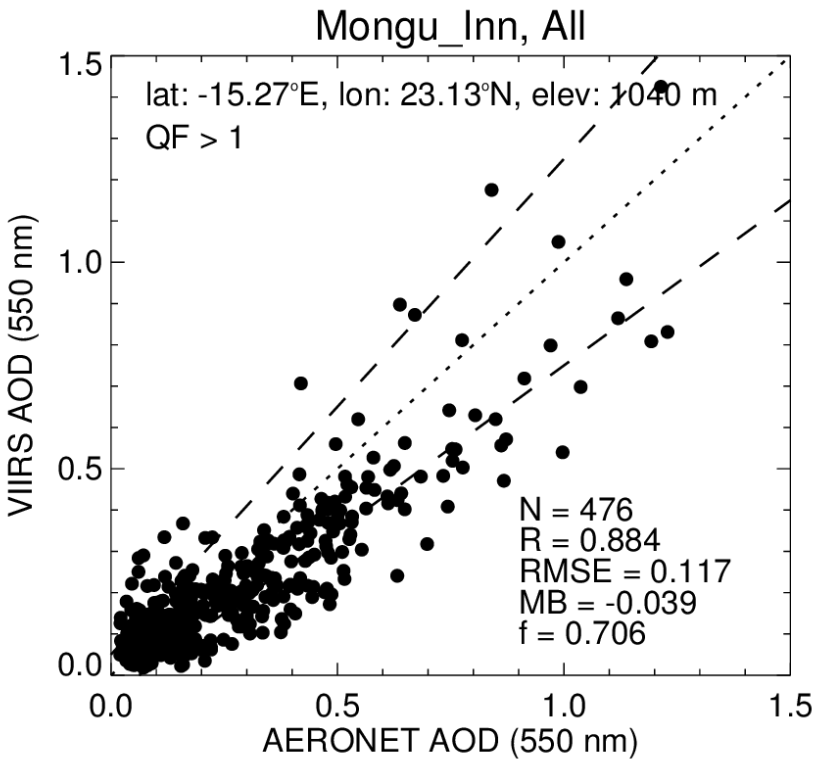


> 1000 m

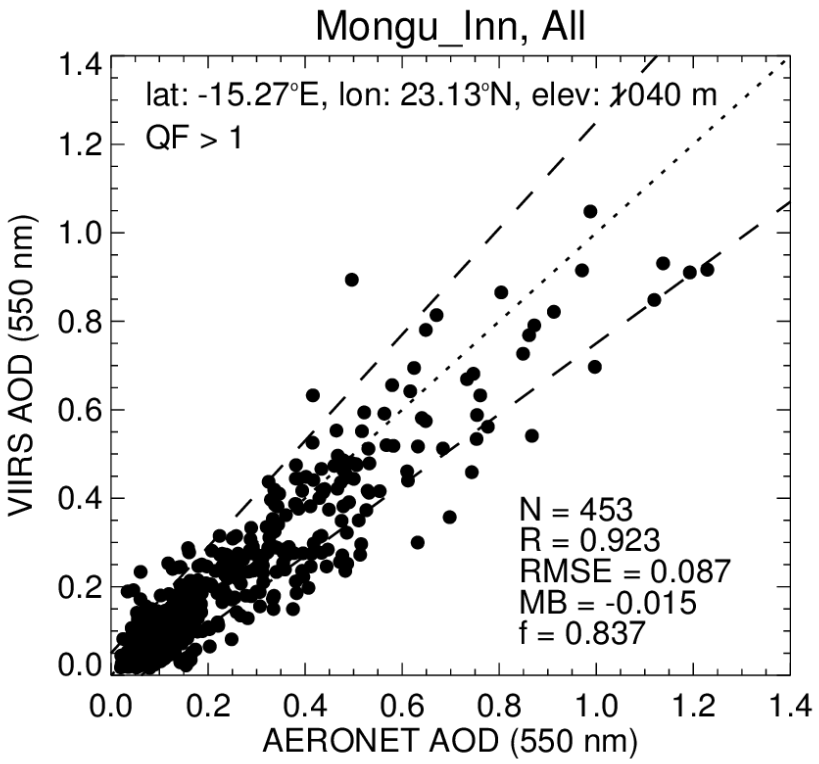
- The DB surface reflectance database has been revised by better accounting for the effects of surface elevation, resulting in improvements of low bias in retrieved AOD over high elevation regions.

Planned Improvements over High Elevation Areas for VIIRS and MODIS

VIIRS version 1



VIIRS version 2

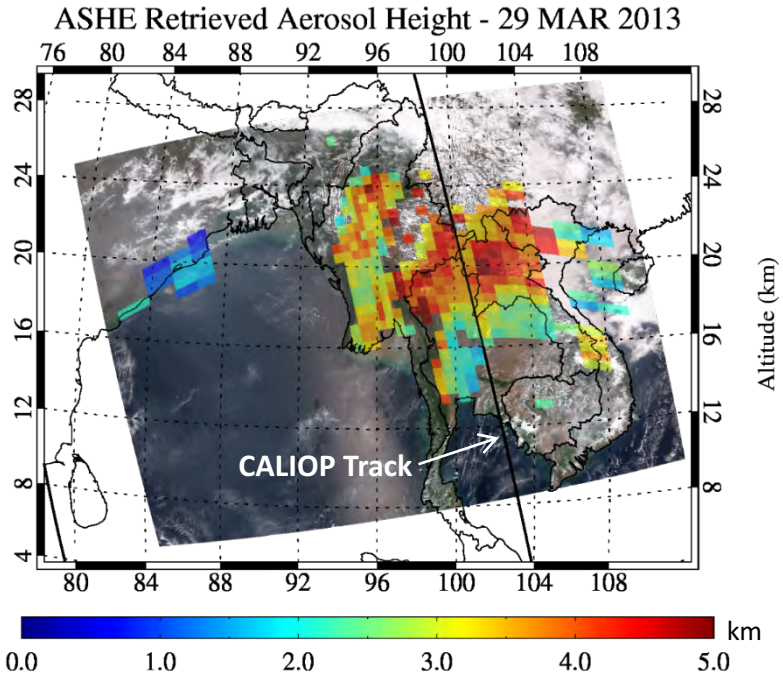


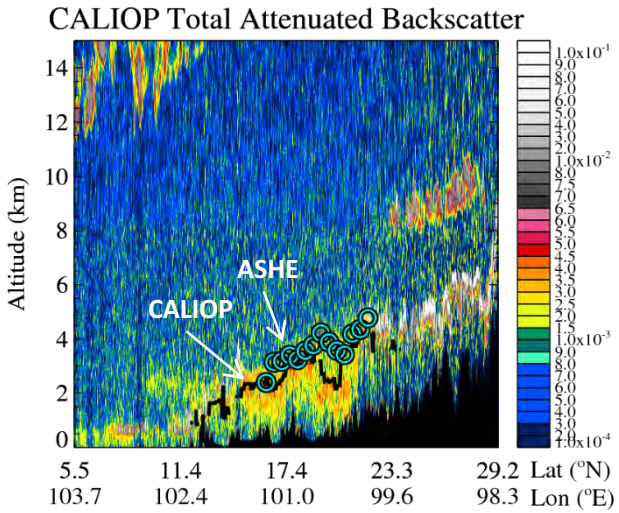
New Aerosol Plume Height Products Using Aerosol Single-scattering albedo and layer Height Estimation (ASHE) algorithm for VIIRS V2 and MODIS C7

References:

1. Jeong and Hsu, GRL, 2008, "Retrievals of aerosol single-scattering albedo and effective aerosol layer height for biomass-burning smoke: Synergy derived from "A-Train" sensors"
2. Lee *et al*., JGR, 2015, "Retrieving the height of smoke and dust aerosols by synergistic use of VIIRS, OMPS, and CALIOP observations"
3. Lee *et al*., AAQR, 2016, "Evaluating the height of biomass burning smoke aerosols retrieved from synergistic use of multiple satellite sensors over Southeast Asia"

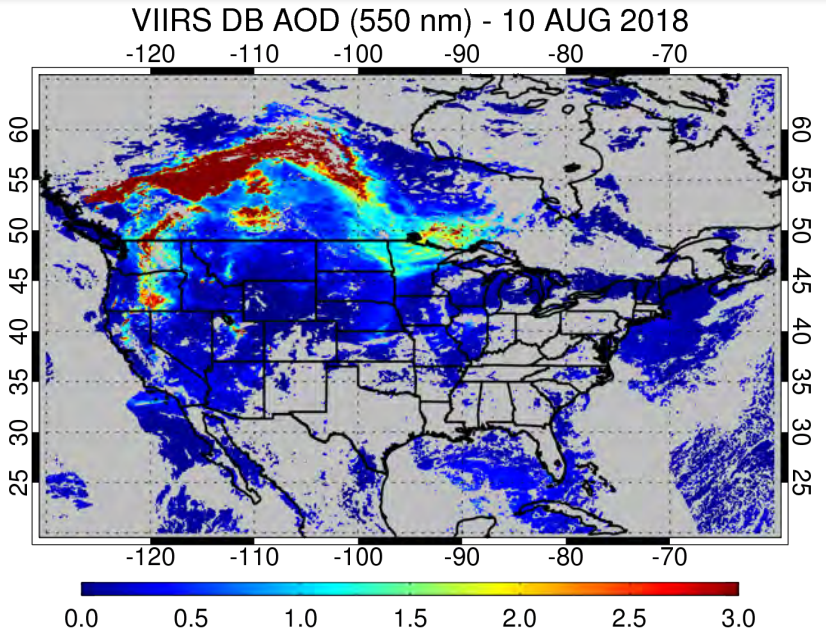
New VIIRS Deep Blue Aerosol Product: Aerosol Plume Height

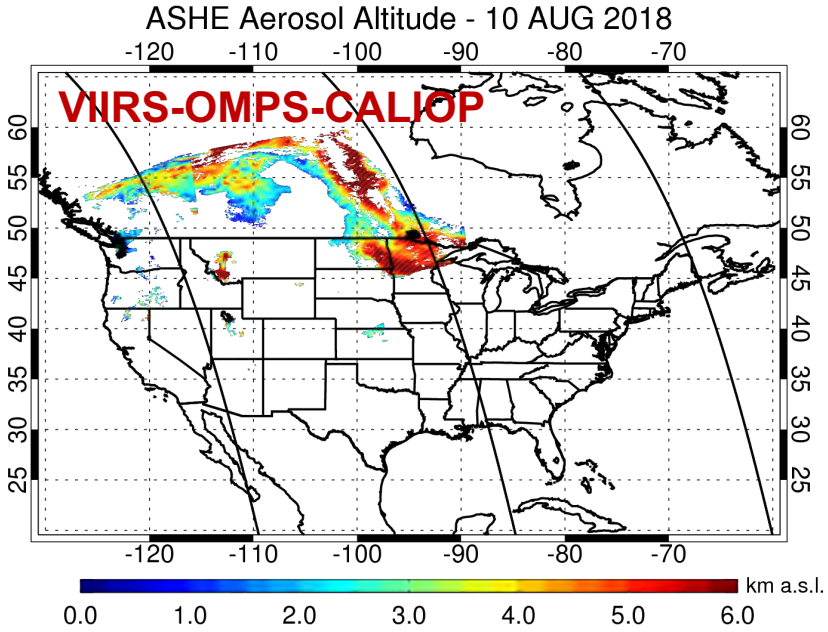


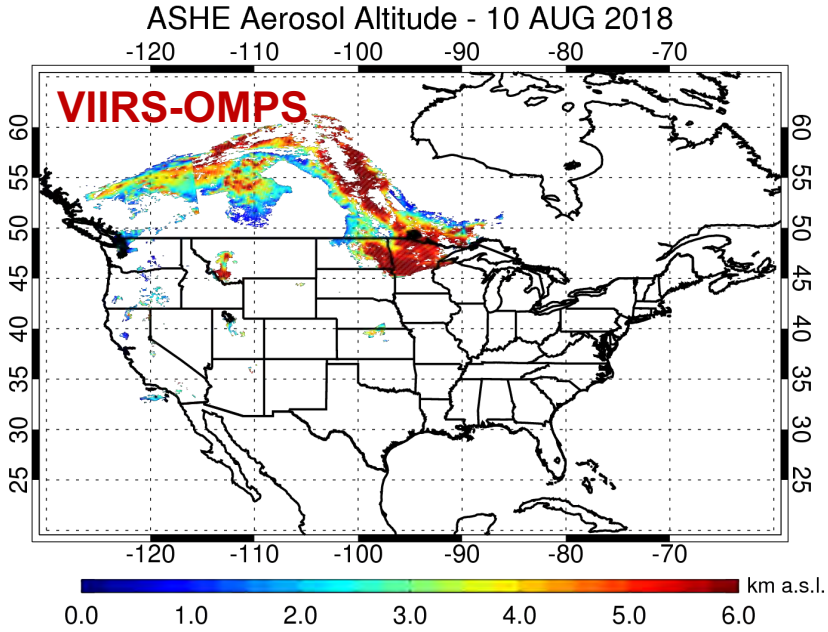


- **Left panel shows retrieved aerosol height from our ASHE algorithm, for Southeast Asian biomass burning.**
- **ASHE combines our VIIRS Deep Blue data with OMPS UV observations to determine aerosol height, which can not normally be retrieved using this type of sensor**
- **Validation with CALIOP profiles shows good agreement (right panel)**

ASHE without CALIOP

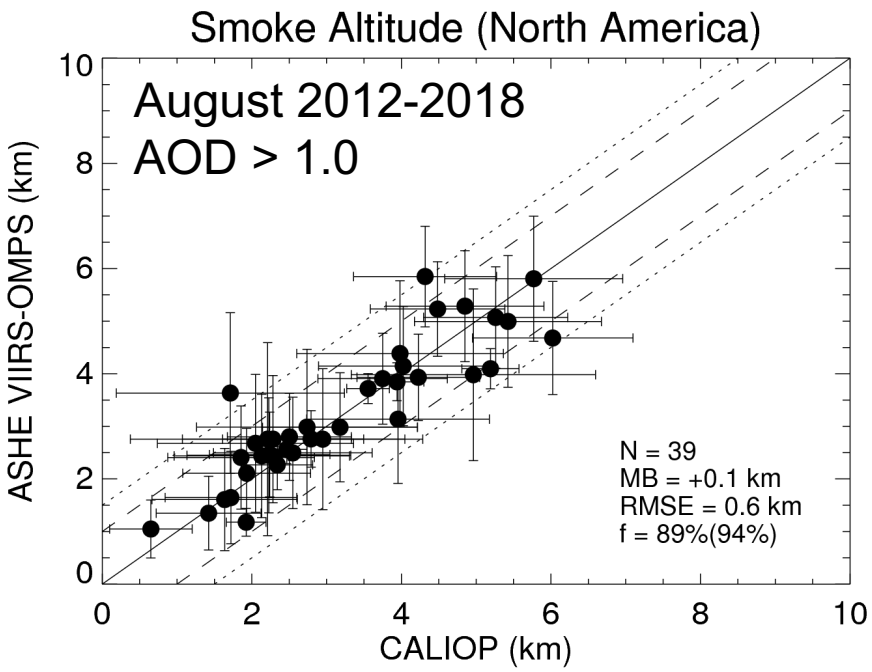




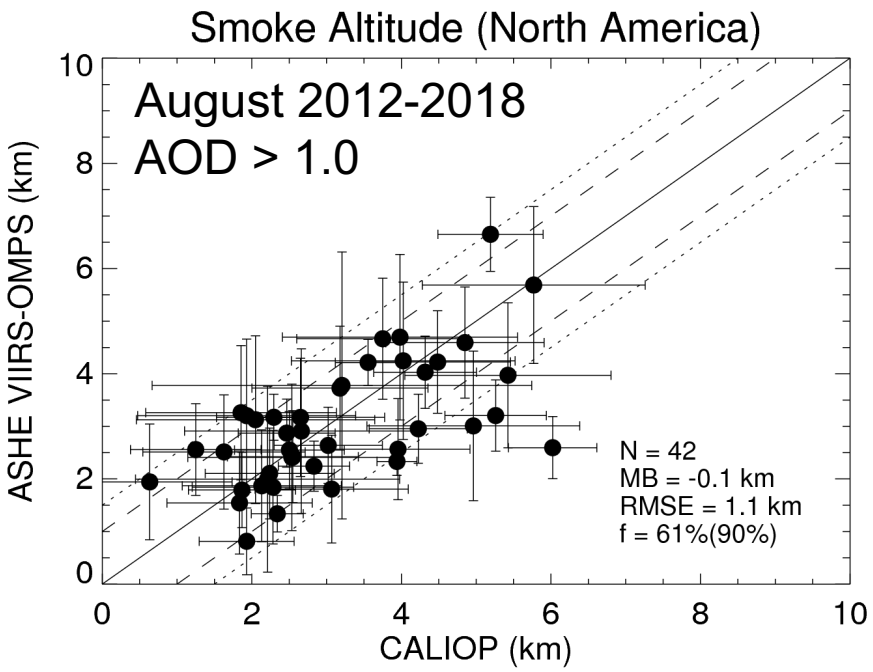


Evaluation against CALIOP over N. America

VIIRS-OMPS-CALIOP

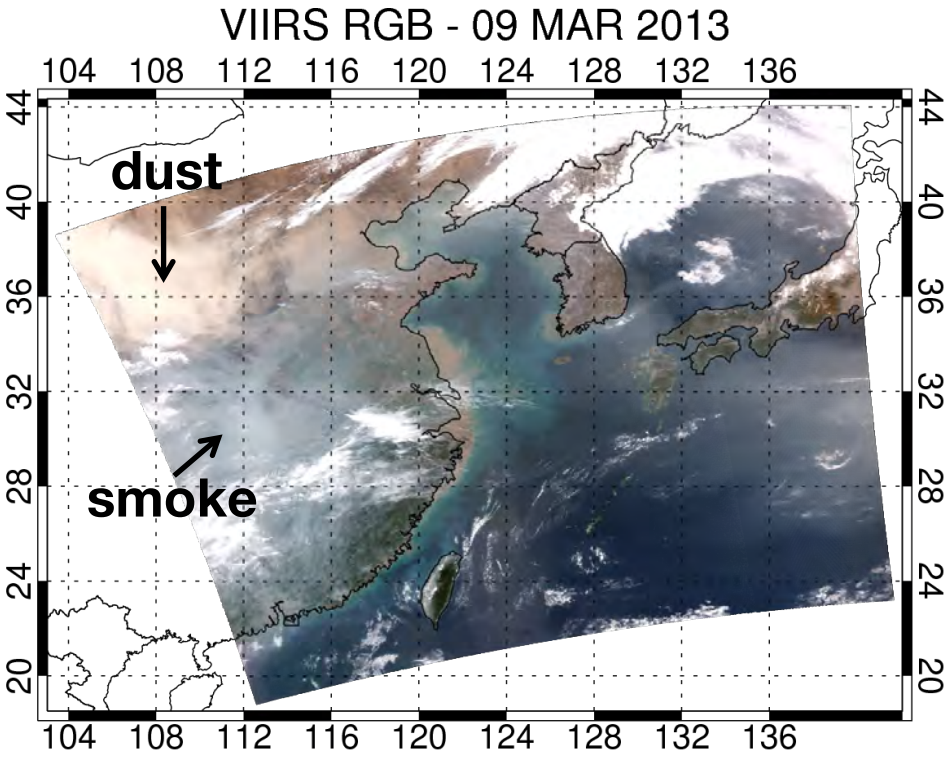


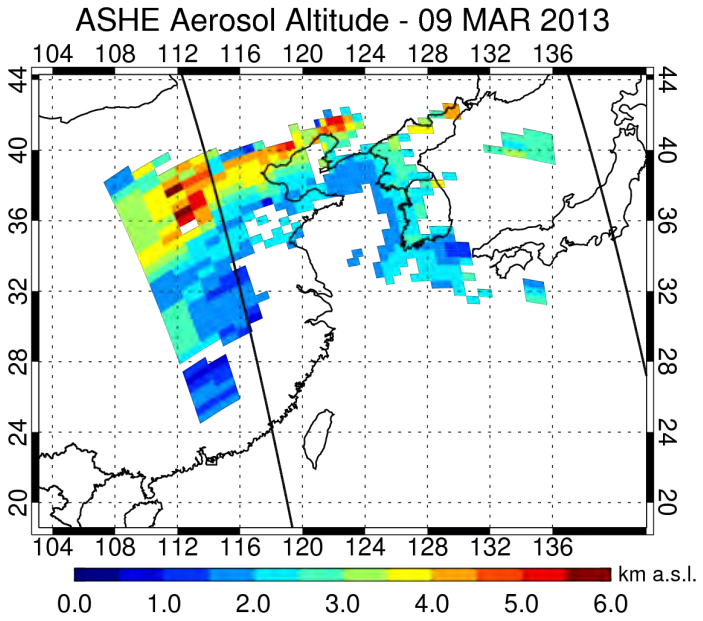
VIIRS-OMPS

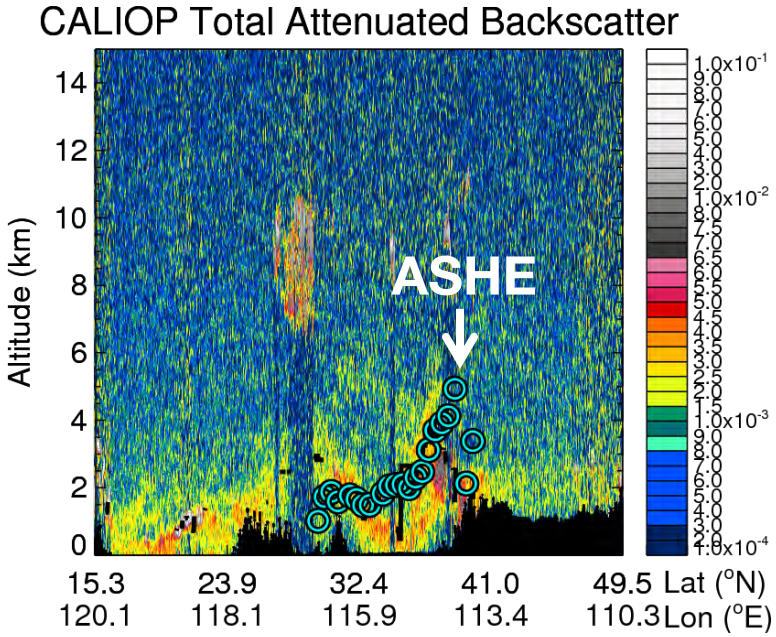


See poster by Jaehwa Lee et al.: “Aerosol layer height from synergistic use of VIIRS and OMPS”

ASHE Extension to Nonspherical Dust







- Application extended to mineral dust layers and VIIRS/OMPS

See poster by Jaehwa Lee et al.: “Aerosol layer height from synergistic use of VIIRS and OMPS”

Extend *Deep Blue* Aerosol Products from Cloud-free to Cloudy regions For VIIRS V2 and MODIS C7

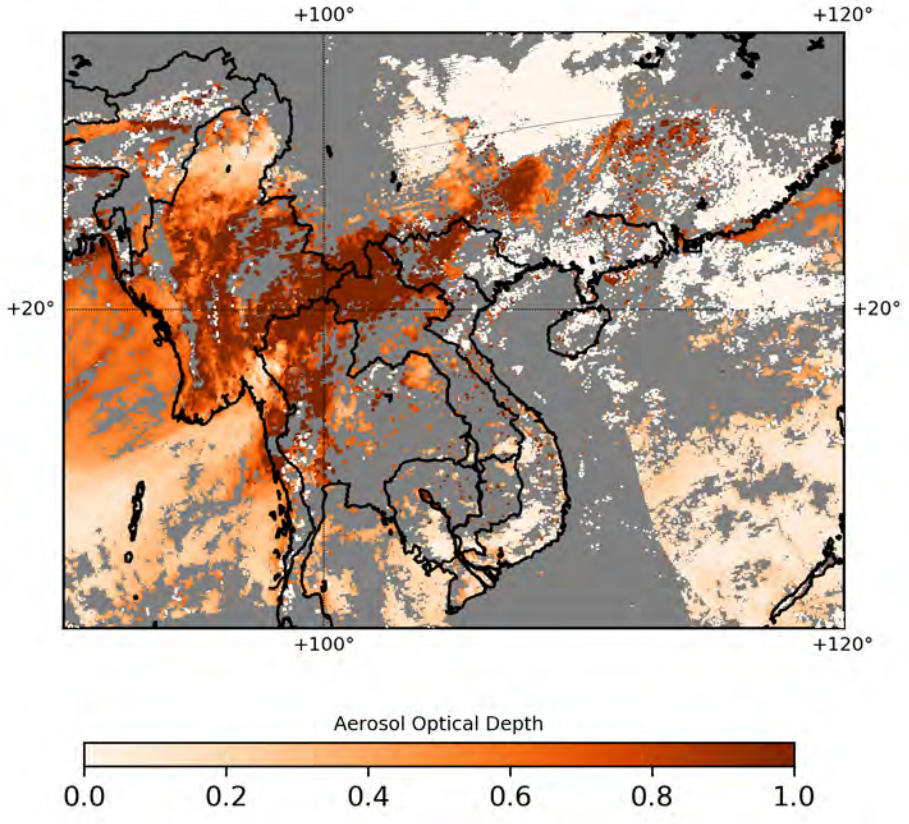
References:

1. Sayer et al., JGR, 2016, "Extending `Deep Blue' aerosol retrieval coverage to cases of absorbing aerosols above clouds: sensitivity analysis and first case studies"
2. Sayer et al., JGR, 2019, "Two decades observing smoke above clouds in the south-eastern Atlantic Ocean: Deep Blue algorithm updates and validation with ORACLES field campaign data"

We can use sensors like MODIS and VIIRS to quantify absorbing aerosols above clouds (AACs)

VIIRS RGB April 2, 2019

Clear-sky and above-cloud AOD



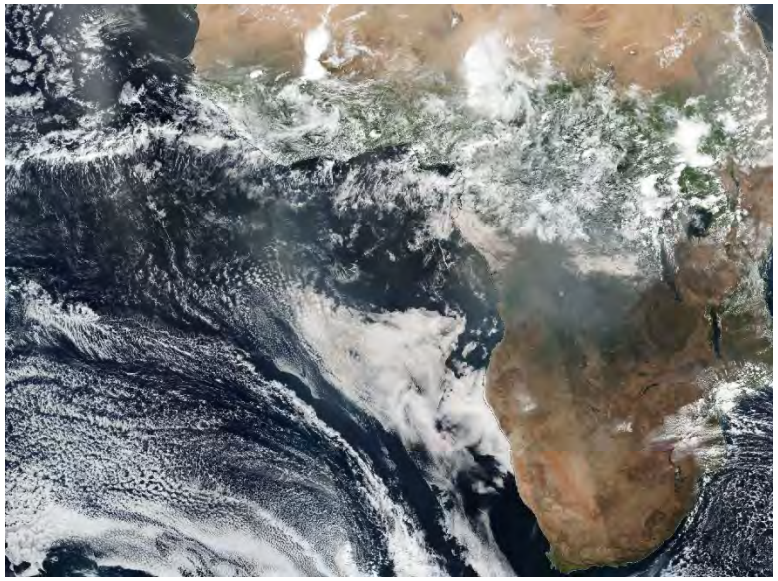
Reference: *Sayer et al.*, 2016, JGR, "Extending "Deep Blue" aerosol retrieval coverage to cases of absorbing aerosols above clouds: Sensitivity analysis and first case studies"

AACs **darken** clouds, and **change the spectral shape** of TOA reflectance

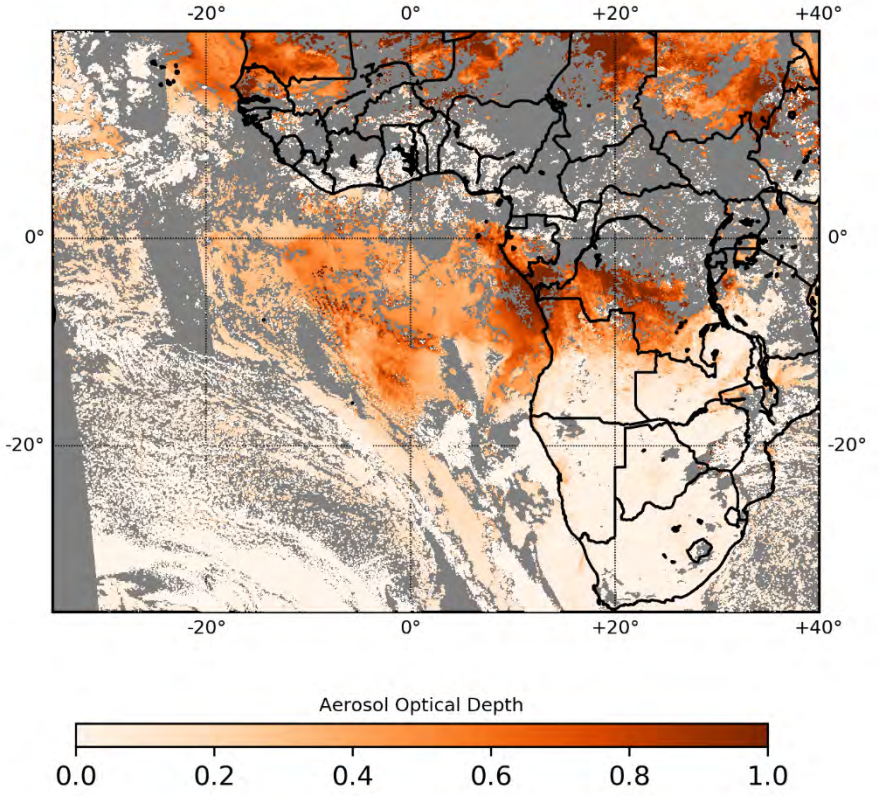
With some assumptions, we can retrieve the **above-cloud AOD** and an estimate of the **COD** of the underlying liquid water cloud

Smoke plumes generated over central Africa are frequently transported westward over low level marine stratus in the Atlantic as seen in our AAC products

VIIRS RGB July 21, 2019

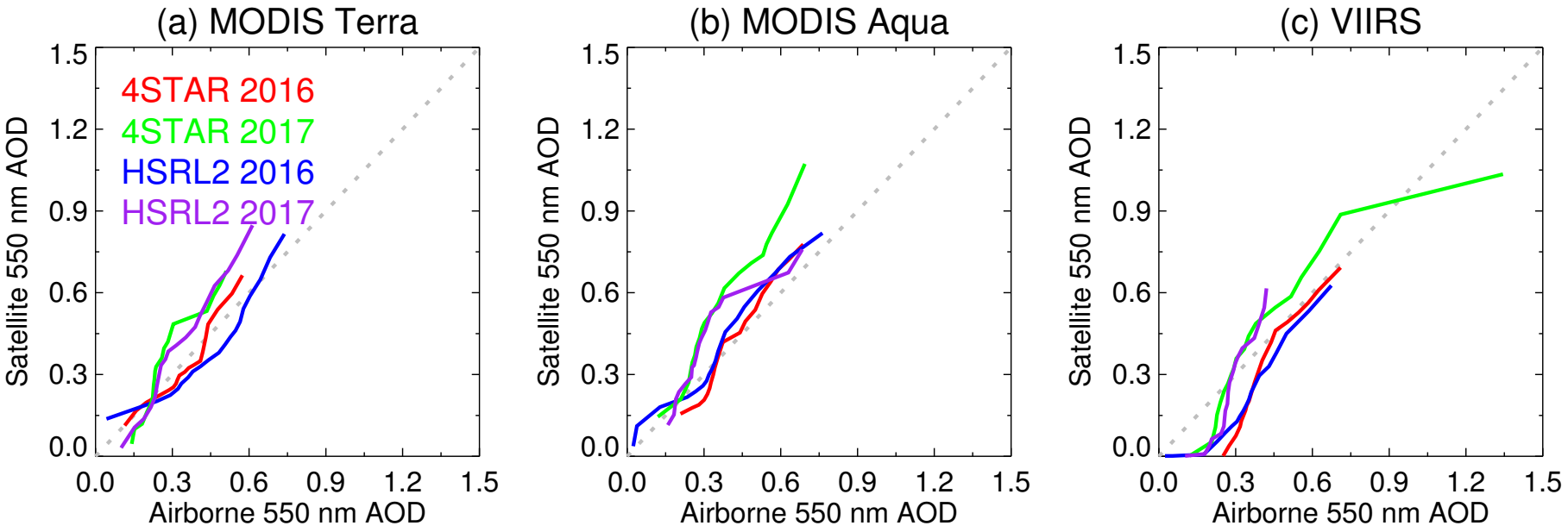


Clear-sky and above-cloud AOD



The AAC retrieval module has been implemented in the Deep Blue operational codes and will provide AAC data in the next version of MODIS/VIIRS products.

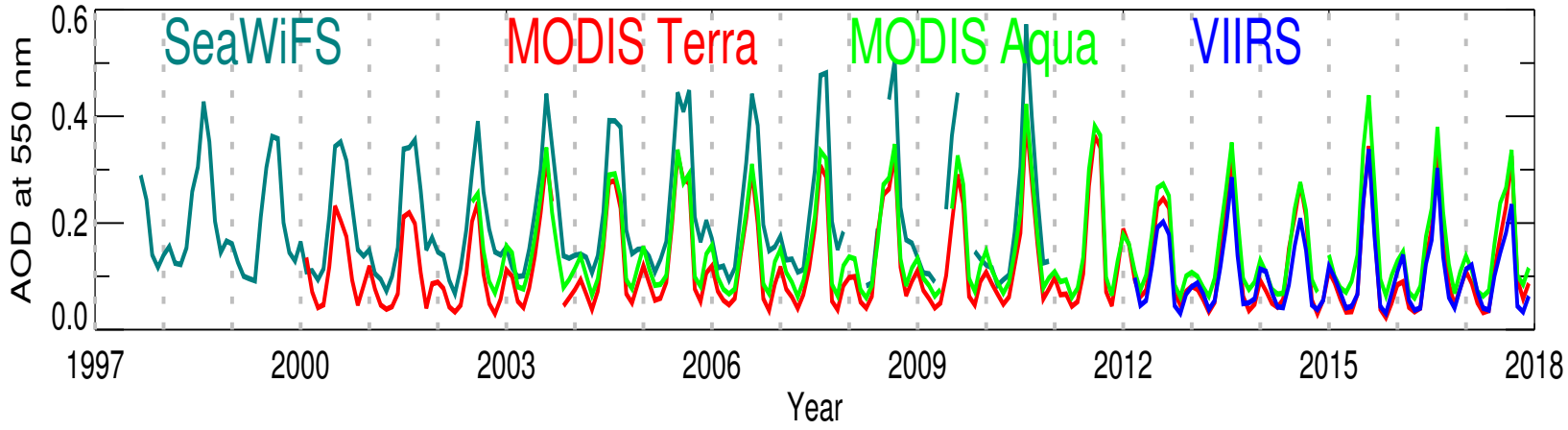
The performances of the DB above cloud AOD are comparable between MODIS and VIIRS against ORACLES airborne data



Quantile–quantile plots comparing distributions of AODs from co-located satellite and airborne measurements, from 5th to 95th percentiles of the matched data

Reference: Sayer *et al.*, 2019, AMT, "Two decades observing smoke above clouds in the south-eastern Atlantic Ocean: Deep Blue algorithm updates and validation with ORACLES field campaign data"

Monthly time series of mean AAC AOD at 550 nm over the S. Atlantic (25°S - 0°N, 15°W - 15°E)



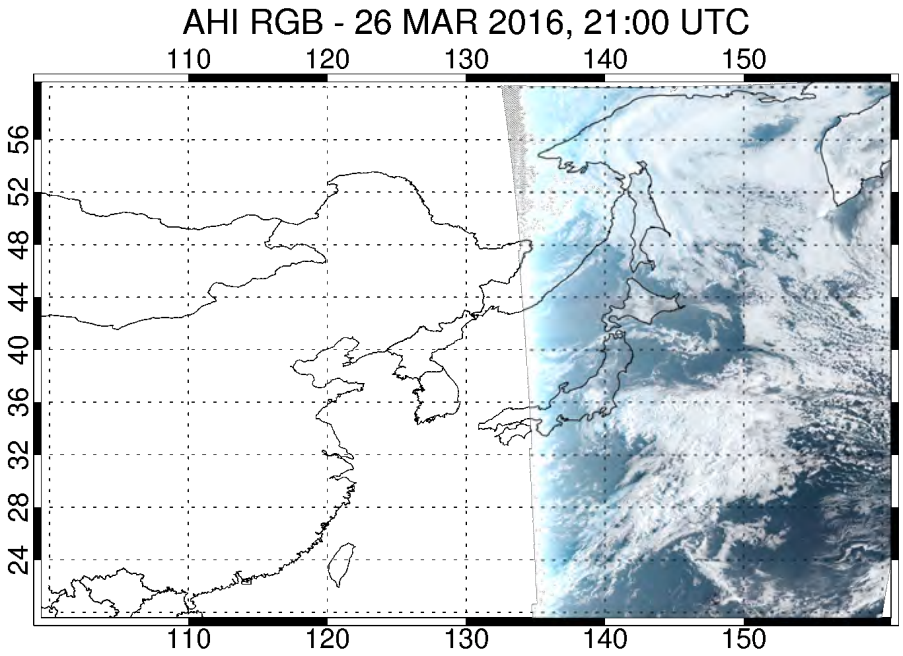
The monthly averaged retrieved AAC data from **MODIS Terra/Aqua** and **SNPP VIIRS** are consistent with each other.

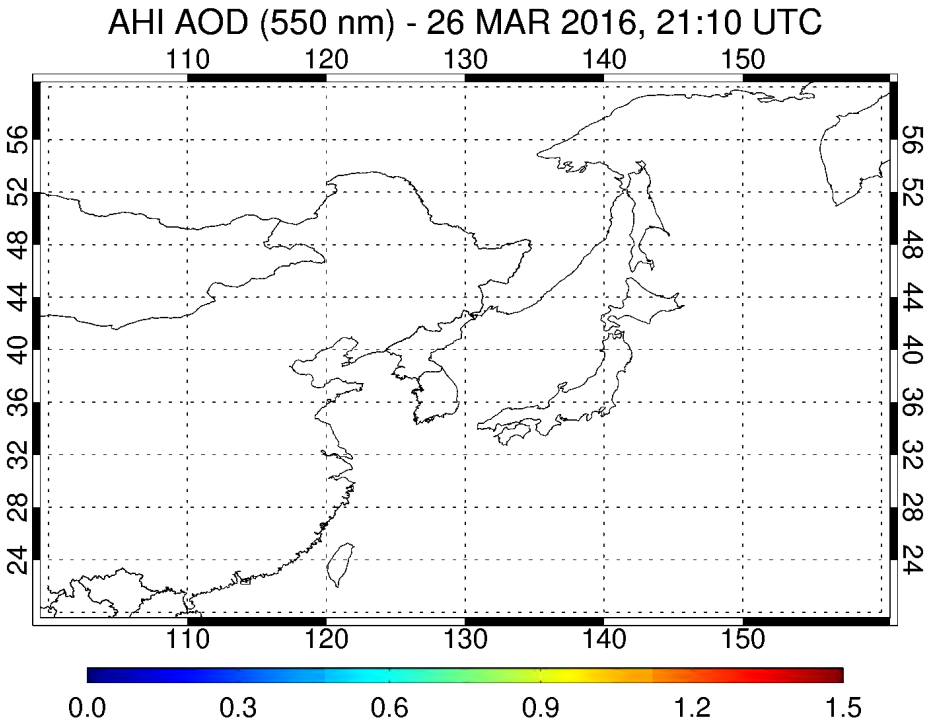
AAC retrieved from SeaWiFS is biased high compared to those from MODIS Terra/Aqua, due to the lack of shortwave and thermal infrared bands.

New Deep Blue Geostationary Aerosol Products from Himawari-8 and GOES-16/17

Biomass Burning Smoke over Korean Peninsula and Fine-Mode Aerosol Plumes over E. Asia

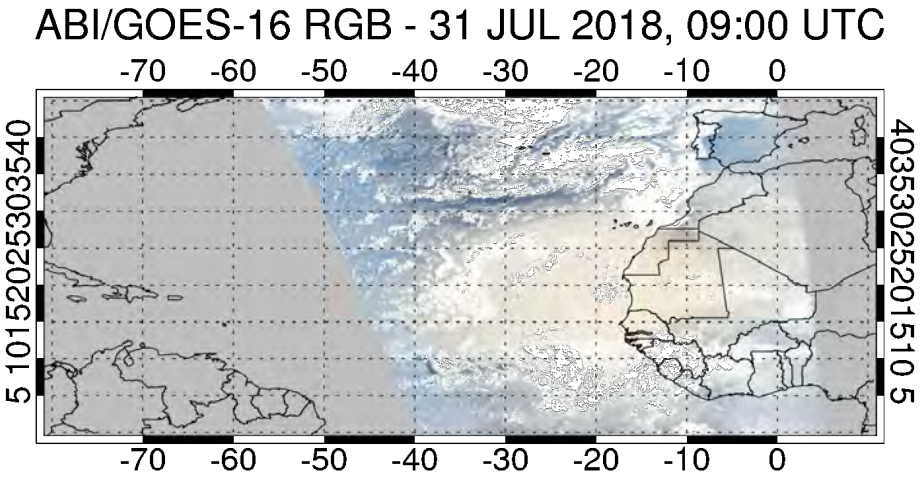
Himawari-8: 10-minute interval

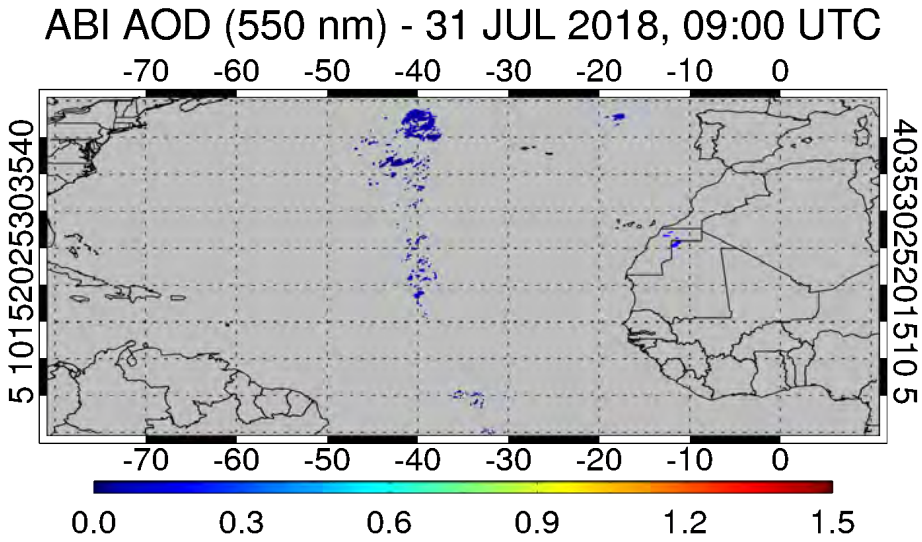




The Saharan Dust transported from N. Africa to the Atlantic Ocean

GOES-16: 15-minute interval





Summary

- **Big Thanks for the supports from Atmosphere SIPS, LAADS and LANCE, standard and NRT VIIRS DB aerosol products are now available operationally, including daily imagery on Worldview.**
- **Based upon the comparisons with AERONET AOD global observations, the expected error for VIIRS DB is 0.05±20% over land and 0.03±10% over ocean, which is comparable to that for MODIS DB. The AOD time series from VIIRS and MODIS are consistent with each other.**
- **Implementations of aerosol plume height and aerosol above cloud retrievals into the Deep Blue operational algorithm are nearly complete and will be used for VIIRS DB V2 and MODIS C7 reprocessing .**